

## What every operator needs to know about secondary clarification

Adam Rogensues



**S**econdary clarification is a vital component of most biological wastewater treatment systems. The fundamental objective of secondary clarifiers is to separate biological floc from the treated liquid waste stream. Secondary clarifiers are most often discussed in conjunction with suspended growth biological wastewater treatment systems. Accordingly, the content of this article is discussed in the context of suspended growth systems.

Knowledge	Principle	Practical consideration
Purpose of secondary clarifiers	Secondary clarifiers separate flocculated biomass from the liquid in waste streams.	Secondary clarifier performance depends on numerous factors, including activated sludge characteristics (settleability), hydraulic loading rate, solids loading rate, return activated sludge flow, and physical features of the clarifier.
Biological factors	Activated sludge settleability is a critical factor in secondary clarifier performance.	<p>Activated sludge settleability often is quantified using the sludge volume index (SVI). SVI is defined as the volume (measured in mL) occupied by 1 gram of suspended solids following a 30-minute settling period. The SVI test traditionally is carried out in a 2-L Mallory settleometer. It is possible to conduct the test with 1- or 2-L graduated cylinders; however, because graduated cylinders have a smaller surface area, this test may not accurately reflect the behavior of the activated sludge in the secondary clarifier.</p> <p>Calculating SVI require two inputs: the volume from the 30-minute settleability test and the mixed liquor suspended solids concentration (MLSS). The equation for calculating the SVI is as follows:</p> $SVI \left( \frac{mL}{gSS} \right) = \frac{SSV_{30} \cdot (1000 \text{ mg/g})}{X \cdot V_T}$ <p>where  SVI = sludge volume index,  SSV<sub>30</sub> = 30-minute settle sludge volume (mL),  X = mixed liquor suspended solids concentration (mg/L), and  V<sub>T</sub> = volume of the settle column.</p>



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Settleometer results	More information can be gained from a settleometer test than just the degree of compaction.	<p>The settleometer test provides three very useful data points:</p> <ul style="list-style-type: none"> <li>■ the settled sludge volume at 5 minutes,</li> <li>■ the settled sludge volume at 30 minutes, and</li> <li>■ the time (if any) for the sludge blanket to “pop” or return to the top of the settleometer.</li> </ul> <p>The settled sludge volume at 5 minutes, <math>SSV_5</math>, is a measurement of settleability. A compact sludge with few filaments will settle rapidly and have a relatively low <math>SSV_5</math>. After about 5 minutes, the sludge in the settleometer will have progressed to hindered settling (particles colliding with one another) and compaction (particles piling up on one another). Because the density of sludge particles in activated sludge is very close to the density of water, water resource recovery facilities that track <math>SSV_5</math> on process control spreadsheets may notice seasonal trends. As water warms in the summer, the sludge will settle faster; as water cools in the winter and becomes denser, the <math>SSV_5</math> will increase.</p> <p>The settled sludge volume at 30 minutes, <math>SSV_{30}</math>, is a measurement of sludge compaction. If filaments are present, the sludge may not compact as well and the <math>SSV_{30}</math> will increase.</p>
Variations of/on the traditional SVI test	SVI may not always be the best measure of settleability. Some SVI test variations can more accurately quantify sludge settleability. However, the traditional SVI test is the most widely used.	<p>The diluted sludge volume index (DSVI) is a notable permutation of the traditional SVI test that is used occasionally.</p> <p>The objective of the DSVI test is to maintain the settled sludge volume between 150 and 250 mL/L. This is achieved by diluting the MLSS concentration with clarified effluent (taken upstream of disinfection). The formula for the DSVI test is</p> $DSVI \left( \frac{mL}{gSS} \right) = \frac{DSV_{30}}{X_d}$ <p>where</p> <p><math>DSV_{30}</math> = settled sludge volume of diluted sludge after 30 minutes of settling and</p> <p><math>X_d</math> = MLSS concentration after dilution (mg/L).</p> <p>The DSVI test may be used to determine if poor sludge settleability is due to a low settling velocity or hindered settling (too much sludge!). In the DSVI test, the operator prepares multiple dilutions of the MLSS with secondary clarifier effluent. If the sludge settles faster—lower <math>SSV_5</math>—after dilution, this indicates that the sludge concentration is inhibiting settling. If the sludge settles about the same regardless of dilution, this can indicate the presence of filaments, bulking sludge, or nutrient deficiency.</p> <p>For other variations on the settleometer test, check out the book, <i>Basic Laboratory Procedures for the Operator-Analyst</i>, published by the Water Environment Federation (WEF).</p>

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Critical hydraulic and loading design and operational considerations	Solids loading rate (SLR)	<p>SLR is defined as the quantity of solids applied per unit of surface area of the secondary clarifiers in service. SLR typically is expressed in pounds of solids per area of clarifier per either day or hour – <math>\text{kg}/\text{m}^2\cdot\text{d}</math> or <math>\text{kg}/\text{m}^2\cdot\text{h}</math> (<math>\text{lb}/\text{ft}^2\cdot\text{d}</math> or <math>\text{lb}/\text{ft}^2\cdot\text{h}</math>).</p> <p>The maximum allowable SLR is a function of upstream biological treatment process (conventional activated sludge, extended aeration, etc.) and sludge settleability. (Note: Return activated sludge flow rates should be included in SLR calculations. Refer to Chapter 20 of <i>Operation of Municipal Wastewater Treatment Plants: Manual of Practice 11</i>, published by WEF, for additional information regarding SLR typical design values and calculation.)</p> <p>When sludge is settling poorly, fewer solids can settle effectively and the maximum SLR is diminished. To reduce SLR, an operator may decrease the MLSS concentration by reducing the sludge age, reducing the return activated sludge rate, placing more clarifiers into service, or artificially adjusting the SVI by adding a polymer or flocculent.</p>
	Surface overflow rate (SOR)	<p>SOR is defined as the volume of flow applied per unit of surface area per unit of time in the in-service secondary clarifiers – that is, <math>\text{m}^3/\text{m}^2\cdot\text{d}</math> (<math>\text{gal}/\text{ft}^2\cdot\text{d}</math>). This parameter is a common design consideration and is included in most textbooks but is used infrequently by operators. SOR essentially is the upward velocity in the clarifier. As long as the pull of gravity and sludge settling characteristics allow the sludge particles to be pulled down faster than the upward surface overflow rate velocity, the particles eventually will end up in the sludge blanket.</p>
	Return activated sludge (RAS) rate	<p>RAS rate is the volume of settled sludge collected from the bottom of the secondary clarifier and returned to the influent of the upstream aeration basin(s).</p>
	Influent flow distribution/splitting	<p>Equitable clarifier influent flow distribution is a critical clarifier operational performance parameter and often is overlooked. It is prudent practice to adjust flow distribution equipment (e.g., influent splitter box weirs/gates) to maintain equitable flow distribution and maximize clarifier capacity. Flow distribution can be checked by monitoring the amount of sludge in the bottom of each clarifier at different times throughout the day.</p>
Traditional performance monitoring	Sludge blanket depth	<p>Sludge blanket depth is an operational process control test in which the depth of sludge accumulated at the bottom of a secondary clarifier is measured, most commonly accomplished using a “sludge judge.” The following link provides a PDF of a classic protocol on conducting this measurement: <a href="http://bit.ly/SBD-HowTo">bit.ly/SBD-HowTo</a>.</p> <p>Prudent practice involves monitoring sludge blanket depth a minimum of once per day or once per shift for multishift operations. A sludge blanket depth of target of .3 to .6 m (1 to 2 ft) is adequate for most treatment facilities. For best performance, a good rule-of-thumb is to maintain the blanket of 0.6 m (2 ft) or less at all times.</p>
	RAS flow rates	<p>A common operational target for RAS flow rates is to maintain flows between 50% and 150% of the total influent flow rate. RAS flow rates often are adjusted within the aforementioned range in response to sludge blanket depths.</p> <p>When selecting a RAS flow rate, keep in mind the following process goals:</p> <ul style="list-style-type: none"> <li>■ Keep rates as low as possible to save energy.</li> <li>■ Do not build a blanket greater than .6 m (2 ft).</li> <li>■ Maintain effluent quality for turbidity and total suspended solids. (This last goal may require some facilities, especially facilities that remove ammonia, to operate at RAS rates over 100% of influent flow.)</li> </ul>
	Effluent total suspended solids (TSS) concentrations	<p>Effluent TSS is a fundamental secondary clarifier performance parameter, as the objective of the clarification process is solids separation. Elevated effluent TSS concentrations often are indicative of clarification failure, particularly during wet-weather events where clarification failure and overloading are more likely. Elevated effluent solids also can be caused by denitrification in the clarifier blanket.</p>

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Advanced performance monitoring	State point analysis (SPA) is a robust analytical procedure that historically has been used by facility designers, but is gaining popularity among operators.	<p>An advantage of the SPA procedure is that it illustrates visually the interrelationship among sludge settleability, SOR, RAS, and SLR to evaluate clarifier performance.</p> <p>For more info on the fundamentals of SPA, download a PDF from the Maine Department of Environment Protection at <a href="http://bit.ly/Maine-SPA">bit.ly/Maine-SPA</a>.</p>
Automated process control	Instrumentation can be installed to improve process control and reduce operational labor requirements.	<p>Common instrumentation includes analyzers for sludge blanket depth, TSS, turbidity, and percent total solids versus TSS as well as monitors for clarifier drive units.</p> <p>Sludge blanket depth analyzers continuously monitor sludge blanket depth. Effluent TSS and turbidity analyzers can be used to continuously monitor and trend clarifier performance and provide high TSS alarms, which may be indicative of clarifier failure. Drive unit monitors can be installed to both monitor drive unit integrity and operation; associated sensors – for example, torque or power draw units – can be used as indirect indicators of RAS concentrations. Sludge concentration meters can be installed to monitor RAS sludge concentrations, which can be used to optimize sludge pumping frequency and rate.</p>
Performance improvements	Temporary polymer addition and installation of internal baffles are common process improvements.	<p>Cationic (positively charged) polymers can be added – typically at a concentration less than 1 mg/L – to improve sludge settleability temporarily. Generally, it is not advised to dose secondary clarifiers with polymers routinely. Site specific polymer selection and optimal doses can be determined via jar testing experiments.</p> <p>Baffles can be installed in both rectangular and circular secondary clarifiers to improve clarifier hydraulic conditions and performance. Two- and three-dimensional modeling is increasing in popularity in assisting with optimal design and placement of clarifier baffles.</p>
Basic troubleshooting	Denitrification, pin-floc, and algae are common process control issues.	<p>Denitrification, or sludge “popping,” within the secondary clarifiers is a common issue for nitrifying activated sludge facilities. Sludge “popping” occurs when conditions in the clarifier encourage denitrification. The nitrogen gas bubbles attach to sludge flocs and float to the surface of clarifier, bringing the attached particles with them. The solids contained in the sludge flocs can carry over the clarifier weirs and jeopardize effluent TSS quality.</p> <p>Pin floc can be described as small, weak flocs that are subject to flotation within the clarifier. Pin floc leads to a more turbid effluent. It is most commonly the result of exceedingly high sludge age. Reducing sludge age often minimizes the occurrences of pin floc.</p> <p>Algae growth within secondary clarifiers is common for uncovered secondary clarifiers. It requires regular maintenance to remove.</p>

**Adam Rogensues** is a registered engineer, certified wastewater operator, and director of structuring at Veolia Water (Indianapolis).